Agent Modeling from a Semiotic Perspective

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- Review of agent concepts
- Systems and semiotic approach
- Project in modeling socio-technical organizatins

AGENCY

- Classes of existing usages of “agent”
  - AI: “Intelligent” actors
  - Software Engineering: super-objects, super-daemons
  - Distributed Information Systems (DIS): Bob
  - Robots: behavior-based
  - ALife: collective automata (boids)
  - Decision theory: political science, collective choice
- Uses
  - DIS: simulation, engineering, user interface (helper bots)
  - Simulation of complex dynamical systems
  - Simulation of natural systems: organisms, humans, ecologies, economies

AGENT CONCEPTS

- Asynchronous, concurrent, parallel
- Interactive, social
- Mobile: code, data, virtual or real space
- Distributed: in real, virtual, or simulated spaces
- Random: statistical trials
- ***Autonomous:***
  - Self-governing, freedom
  - Auto + nomos (law), *not* auto + nomen (name)

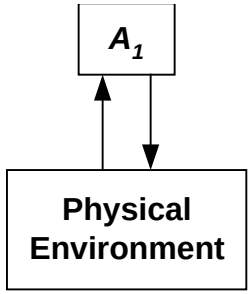
AUTONOMY

- Boundaries: but with respect to what?
  - Spatial, temporal, functional
- Autonomy admits *degrees*
- Identity, discreteness: tagging
- As a form of *closure*
  - Physical: structural boundaries
  - Causal: encapsulation
  - Functional: input/output
- Closure with respect to ***action:***
  - Agents as having freedom of decision-making, *"free will"*
  - At least unpredictability, uncertainty over outcome
  - What/how distinction not sufficient

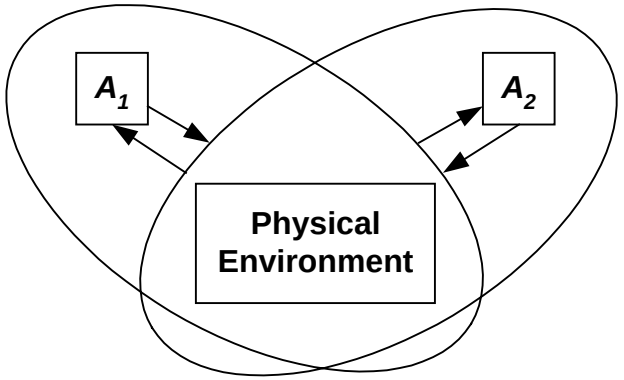
SYSTEMS FOUNDATIONS

- System-environment distinction
  - Emergent behavior from agent-environment interaction
- Environments of agents
  - Absolute: real or simulated phyiscal environment
  - Relative: physical environment plus other agents

Single Agent



Multi-Agent



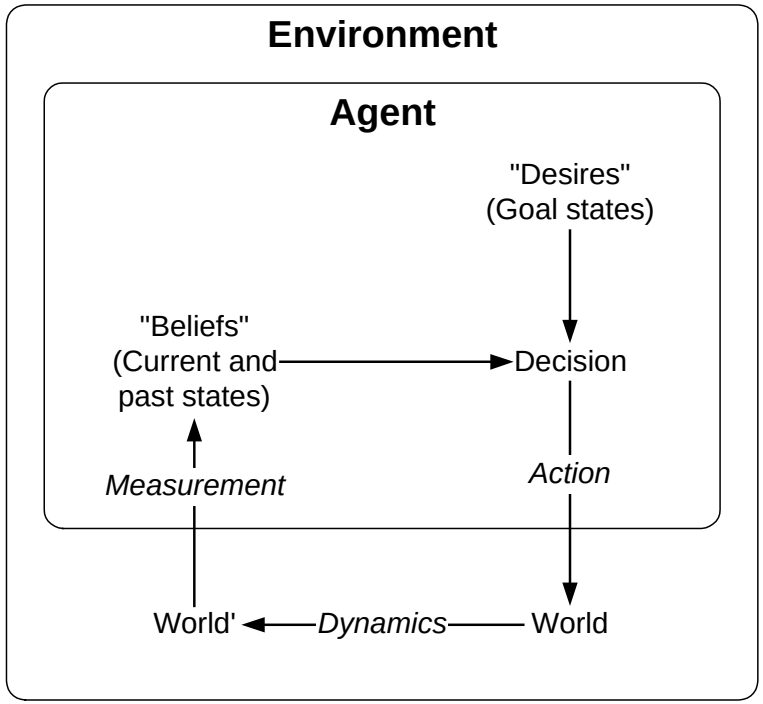
DYNAMIC VS. “SEMIOTIC” AGENTS

- Dynamc: functional, causal autonomy
  - *Dynamically coherent* with their environments
  - Agents with input, output, and state
  - Dynamic self-organization (attractor behavior)
  - Examples:
    - Physical systems following natural laws
    - Purely instinctual agents following natural propensities
- Semiotic: autonomy of action
  - *Dynamically incoherent* with environment: also have *memory*
  - “Dynamical opacity": cannot be modeled as dynamical systems, instead requires modelling as decision-making systems
  - Examples
    - Software agents of sufficient complexity
    - Organisms, people

AGENT SYSTEMS

- Small collections of simple agents
  - Limiting cases: composition of automata, "collective automata", simple robot interactions
  - Possibility of analytical global descriptions
- Large collections of simple agents
  - Traditional ALife approach
  - Limiting case: statistical physics
  - Experimentation, statistical descriptions
- Small collections of complex agents
  - Limiting cases: one or two "intelligent" unmanned vehicles
  - Towards full AI, game theory
- Our goal:
  - Between AI and collective automata
  - Memory-based systems with uncertainty structures

CONTROL STRUCTURE OF "SEMIOTIC AGENTS"



BOUNDED FREEDOM on decision making

- Generalized control relation feedback loop
- Beliefs and desires as relatively simple uncertainty structures, non-propositional
- Reduce error between perceived and desired state
- Decision among possible actions to accomplish goals
- Consequences of actions reflected through environmental dynamics

TOWARDS “SEMIOTIC CONTROL”

- *Representations* required of:
  - Measured states of affairs
  - Goal states
  - Possible actions
- System-environment coupling
  - Rich enough environment to avoid pure decision-making
  - Not so rich as to over-constrain decision-making
  - Reflexively involve other agents: not to regress
- Perception-action coupling
- Closed-loop control

SEMIOTICS

- General theory of representations: signs and symbols
- Originally from linguistics and humanities:
  - Text and media analysis
  - Animal call systems
  - Theoretical biology
- Concerns:
  - Sign typologies
  - Digital/analog, symbolic/iconic representations
  - Motivation: intrinsic relations of sign to meaning
  - Mappings among representational systems, analogy, metaphor, category theory
- Results
  - Modeling epistemology
  - Emphasis on *sources* of codes

SEMIOTIC “DIMENSIONS”

- Syntax:
  - Relations among tokens, production of new tokens
  - Usually formal
- Semantics:
  - Signs *interpreted* by agent as standing-for environment observables
  - Measurement, actions
- Pragmatics:
  - Repercussions of sign interpretations for the agent in the environment
  - Purpose: goals, desires
  - Ultimate criteria: survival

EXAMPLE OF A SIMPLE SEMIOTIC CONTROL SYSTEM

- Organism living at an aqueous thermocline
- Three perceptual states: S={h=too hot,c=too cold,r=just right}
- Three actions: A={u=go up, d=go down, n=do nothing}
- Pragmatics:
  - Organism survival depends on not going up when hot or down when cold
  - Evolution ultimate source of selection
- Semantics:
  - “Too hot” *means* “go down”
  - “Too cold” *means* “go up”
- Syntax:
  - Mapping perceptions to actions
  - Only 3 out of 27 possible codes f : S -> A lead to survival

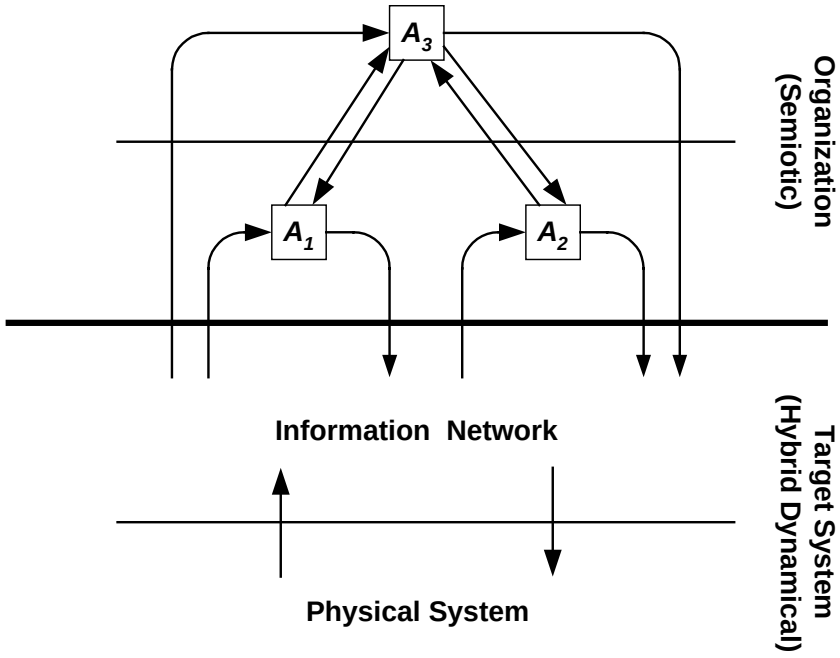
CONSEQUENCES OF THE SEMIOTIC PERSPECTIVE

- Agent-dependence (subjectivity, relativism, *constructivism*):
  - **Interpretation:** Signs (symbols) never have meaning in and of themselves, but only as *interpreted* by an agent
  - **Local Knowledge:** Agents only have access to world-as-perceived
  - **Dependence on Measurable Quantities:** Many given from construction of agent
- Internal Models (Endo-models):
  - Anticipatory Control: Predictions made about consequences of various choices
  - Distinguished from global model of environment
- Reflexive modeling:
  - Models of the environment, of other agents
  - Models of other agent's models of the environment and of self
  - To regress?

ARCHITECTURE OF AGENT SIMULATIONS

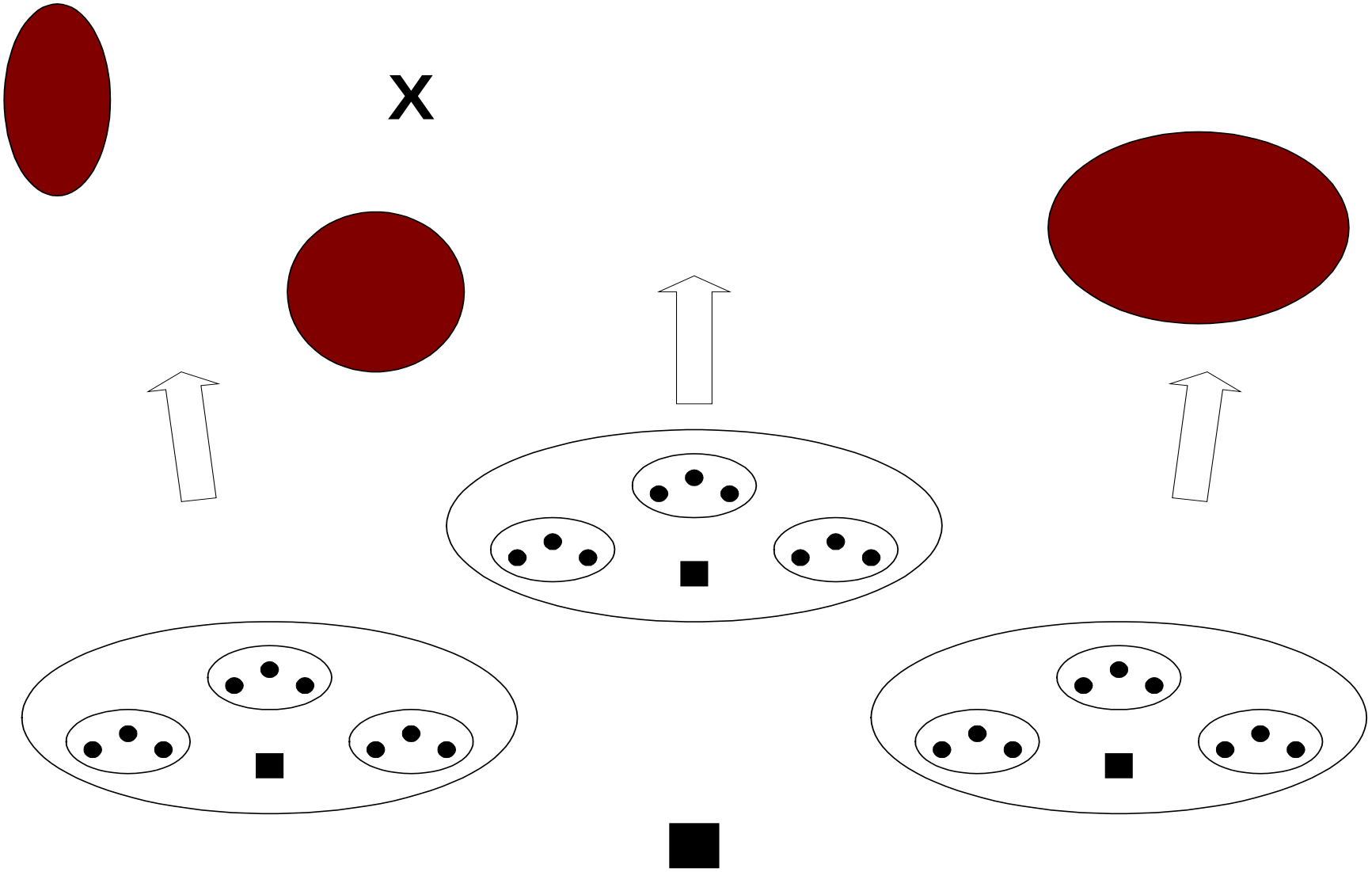
- **Environment:** ``Virtual physics'' of the simulation
- **Action Capabilities:** Relative to that environment
- **Decision Capabilities:** Relative to those possible actions
  - Input/output state systems
  - Evolutionary (external selection) or adaptive (internal selection)
  - Culture as shared knowledge among agents
- **Data:** Information transmission among agents
- **Knowledge:** *Interpretations* of data by agents
- **Internal Structures:** State, memory, decision function
- **Communication:** Relative to knowledge, internals
- **Control:** Decentralized
  - As constraints over decision-making
  - Sources from *all* of the above

SOCIO-TECHNICAL ORGANIZATIONS



- **Target System:** environment for organization
- **Organization:** of semiotic agents
- Functionally defined boundary:
  - Computer agents in organization
  - Deterministic humans in target system
- Decision/coordination structures mediated by net

SCENARIO - SEARCH AND RESCUE



CONSIDERATIONS FOR OUR APPLICATION

- Command Hierarchy:
  - Not flat collective automata
- Data vs. Information:
  - Universal data vs. hierarchical information
  - Intention, attention, scope
- Communication as action?
- External Constraints:
  - Shared knowledge: training, maps
  - Shared goals: common tasks, sub-tasks
  - Information channels and modalities
  - Physical system (breakdowns, terrain)
- Control vs. direction:
  - Control as constraint on decision freedom
  - Possible for lower levels to control upper?